

SUMMARY OF FUNNEL CLOUD OCCURRENCES AND COMPARISON WITH TORNADOES

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ABSTRACT

Climatological and environmental conditions associated with funnel cloud occurrences without tornadoes have been examined and compared with corresponding conditions of the tornado environment. The purpose was to determine if there were significant environmental differences between these two weather phenomena. Seasonal and diurnal distributions, air mass instability, tropospheric vertical wind shear, and geographical distributions are compared.

The overall results show that the funnel cloud environmental characteristics are statistically very closely related to those of the tornado. As with the tornado environment, a large lower tropospheric vertical wind shear is observed. This is thought to be an important dynamical feature of both the tornado and the funnel cloud.

1. INTRODUCTION

The funnel cloud is defined by Huschke (1959) as a "cloud column or inverted cloud cone, pendent from a cloud base." He notes that "this supplementary feature occurs mostly with cumulus and cumulonimbus; when it reaches the earth's surface it constitutes the cloudy manifestation of an intense vortex, namely, a tornado or waterspout." The funnel cloud is also popularly known as a "funnel aloft", or a "funnel cloud aloft". In the present context, the funnel cloud designation means that this feature was observed aloft but that neither the cloudy manifestation of the vortex nor the probable swirling winds were observed at the surface.

Funnel clouds are often observed in conjunction with tornadoes, or tornadic outbreaks. Interesting observations of this association have been provided, for example, by Reber (1954), Fujita (1960), and Hoecker (1960). These authors and others have cited the evolution of full-fledged tornadoes from funnel clouds. Most reported occurrences of funnel clouds appear to be independent of tornadic activity, however. This is verified by the lack of corresponding wind damage or tornado reports at or nearby most funnel cloud occurrence locations. Examination of funnel cloud reports from the period 1950 through May of 1969 reveals that less than 5 percent of the events reported as funnel clouds had corresponding wind damage or tornado reports in their vicinity. The presence of a tornado amid funnel clouds would usually give rise to a tornado report bearing a remark indicating that funnels aloft were also sighted.

Asp (1963), in his discussion of the history of tornado observations, noted that funnel clouds generally had not been considered as tornadoes although at times they had been included in the tornado statistical data. During the period 1932-56, funnel clouds were characterized as tornadoes in the report listings with the notation that the funnel cloud sighted had not touched the ground. Beginning in April 1957, these events were identified as funnels aloft in the listings of severe local storm data and were separately summarized in the monthly and annual climatological summaries.

In addition to the monthly and annual summaries of

funnel cloud occurrences, several special summaries have been published. Wolford (1960) presented a summary of funnel cloud occurrences over the United States for a 6-yr period, 1953-58. More recently Pautz (1969) published a summary of funnel cloud occurrences for the period 1955-67. Other than these summaries, no comprehensive analysis of nationwide funnel cloud occurrences and their environmental circumstances has been published.

The availability of independent funnel cloud and tornado data and the recent statistical information on the tornado environment by Wills (1969) have made it possible to observationally explore the following question—are there any significant differences between the environmental conditions which produce funnel clouds and those which produce tornadoes? This paper attempts to answer that question.

2. DATA SOURCES

Detailed listings of funnel cloud occurrences were taken from the National Oceanic and Atmospheric Administration (NOAA) publications *Climatological Data—National Summary* for the years 1950-58 and *Storm Data*¹ for the years 1959 through the first half of 1969. Other funnel cloud information was obtained from Wolford (1960), Gerrish (1967) and Pautz (1969). The last publication was derived from the severe weather occurrence log maintained by the National Severe Storms Forecast Center and is not exactly comparable to the other data used. Upper air data were abstracted from *The Northern Hemisphere Data Tabulations*. Comparative tornado data were found in Wolford (1960), Wills (1969), Pautz (1969), and in the *Storm Data* information.

3. PROCEDURE

The severe local storms data published in the *Climatological Data—National Summary* and *Storm Data*, for the period 1950 through May of 1969, were examined for funnel cloud occurrences. If a reported funnel cloud had associated surface wind damage, it was rejected as prob-

¹ Published monthly by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, National Climatic Center, Asheville, N.C.

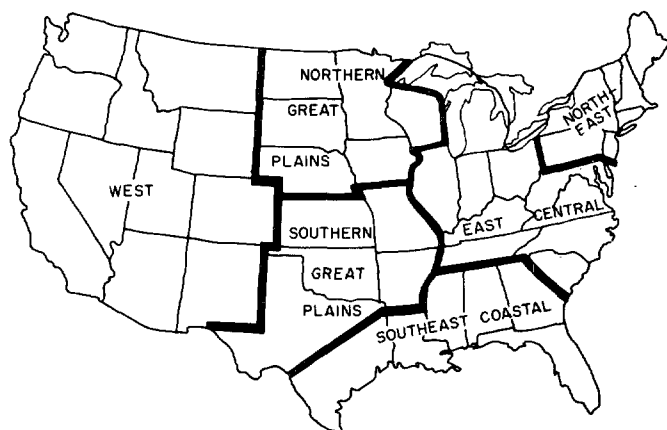


FIGURE 1.—Geographical regions for stratification of funnel cloud data. The regions closely approximate the geographical stratifications employed by Wolford (1960).

ably being tornadic in nature. Simultaneous multiple sightings of funnel clouds were treated and counted as one occurrence. This search revealed 7,388 suitable funnel cloud reports. These funnel cloud events were further screened for funnel cloud occurrences which were within 50 statute miles and $2\frac{1}{2}$ hr of an available upper air sounding. There were 304 events which complied with this criterion. A further requirement was that funnel cloud events having proximity-soundings were to be devoid of corresponding wind damage or tornado reports in their vicinity, thereby insuring independence.

Next, all 7,388 occurrences were stratified into the regional groupings shown in figure 1. Further stratifications by month, hour, and state density were also made.

Vertical profiles of the magnitudes of mean vector vertical wind shear and mean equivalent potential temperature (θ_e) were computed from the 304 proximity-soundings. Regional mean vertical wind shears for the East Central region, the combined Northern and Southern Great Plains, and the entire United States east of the Rocky Mountains, excluding the Gulf Coast and Florida, were also computed. The equivalent potential temperature profiles were averaged only for those Great Plains funnel cloud occurrences for which corresponding soundings were taken within the warm air mass.

4. DISCUSSION OF RESULTS

Figure 2 compares the recent yearly variation in the reported independent occurrences of funnel clouds and tornadoes. This figure's funnel cloud yearly totals include the numbers from multiple sightings. Elsewhere in this study, however, multiple sightings are treated and counted as one event. The tornado data was obtained from Wolford (1960), and the NOAA *National Summary of Climatological Data*. The years prior to 1957 are not shown because official tornado summary statistics are not independent of funnel cloud reports.

The close similarity of the independent funnel cloud and tornado reports for most years was not expected.

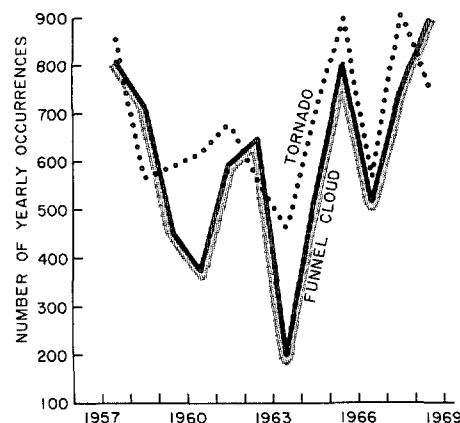


FIGURE 2.—Yearly variation of funnel cloud occurrence in the United States. Tornado occurrence is shown for comparison.

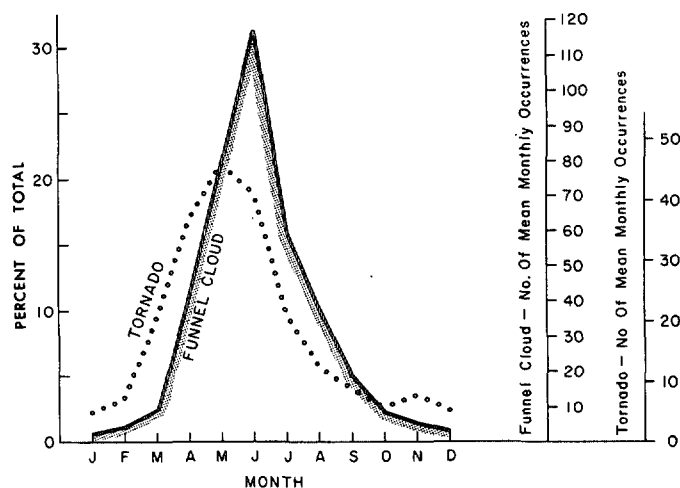


FIGURE 3.—Distribution of funnel cloud and tornado occurrences for the United States by month. The numbers of mean monthly occurrences are based on 19 yr of funnel cloud reports, and 40 yr of tornado reports.

This fact suggests that, if the funnel cloud is always a precursor of the tornado, then the funnel cloud (on a yearly basis) has roughly equal probability of touching down and becoming a tornado. This is probably an invalid conclusion—funnel clouds may be more under-observed than tornadoes because of lack of public awareness and the difficulty of viewing the silent, nondamaging funnel aloft at night. For these reasons, funnel clouds² are thought to be more numerous than tornadoes.

COMPARATIVE DISTRIBUTIONS

Seasonal Distribution. Figure 3 shows the monthly distribution of funnel clouds and tornadoes for the entire United States. The mean monthly occurrence and normalized monthly percent of yearly totals are presented on left and right ordinates, respectively. It is seen that the national peak of tornado activity is in May, while the

² Funnel cloud totals in figure 2 are not exactly comparable with other climatological summaries because of the filtering applied to the reports in order to insure independence from tornado occurrence.

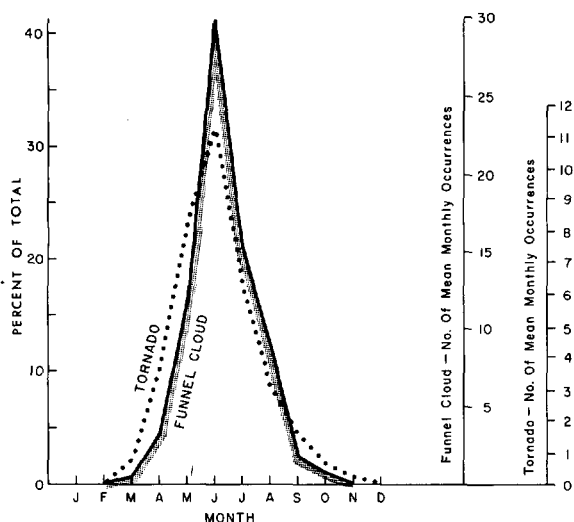


FIGURE 4.—Same as figure 3 for the Northern Great Plains.

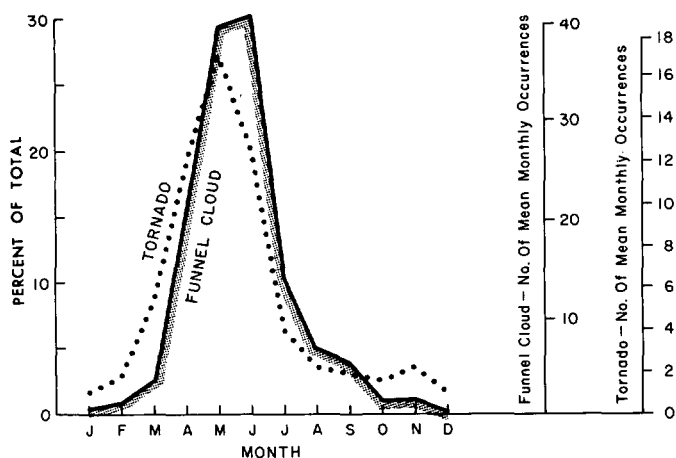


FIGURE 5.—Same as figure 3 for the Southern Great Plains.

peak of funnel cloud activity is in June. This is not true in all regions, however.

In the Northern and Southern Great Plains where the bulk of the nation's vortex activity occurs (figures 4 and 5), monthly funnel cloud and tornado activity is closely correlated and maximum activity is in May and June. Figure 6 shows that funnel cloud activity is also maximum for June in the Northeast, East Central, and Western regions of the United States, although the number of occurrences there is considerably smaller. Tornado seasonal distribution nationwide tends to follow the same pattern as the funnel cloud, except that as the Southeast Coastal region is approached from the interior, a larger difference in the distributions is increasingly apparent.

In the Southeast Coastal region (fig. 7), tornado activity peaks in April, while the funnel cloud activity peaks 2 mo later. Southern Florida is on a yearly cycle of its own. Gerrish (1967) has shown that Miami and vicinity has a distinct July funnel-cloud peak. His data for southern Florida also show a relatively constant May to September summer peak in tornadoes. The peak

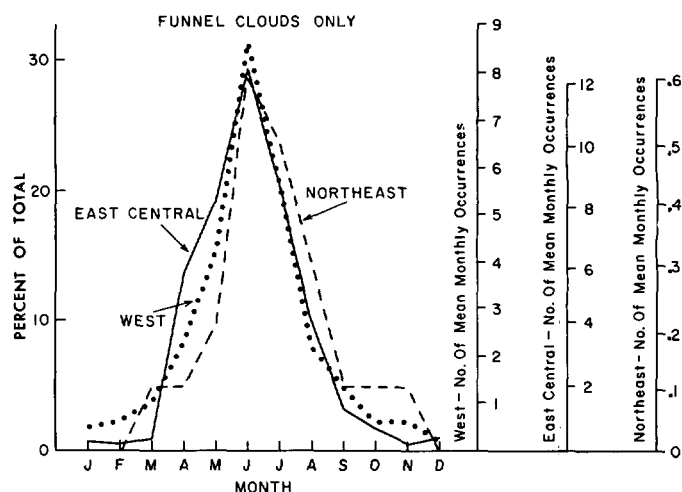


FIGURE 6.—Seasonal distribution of funnel cloud occurrences only, for the East Central, Northeast, and West regions.

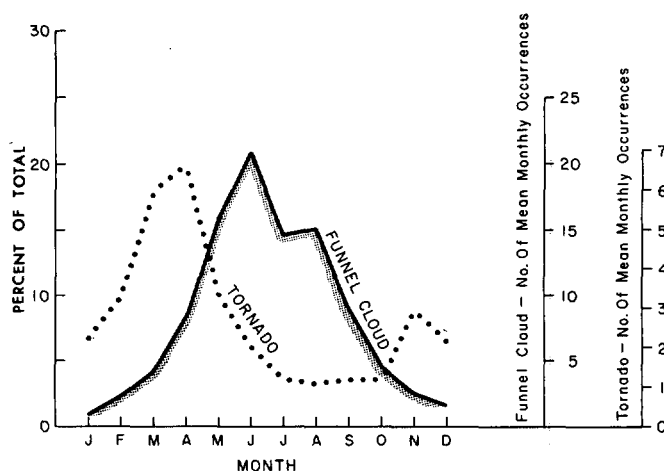


FIGURE 7.—Same as figure 3 for the Southeast Coastal region.

of tornado activity along the Mississippi-Alabama-northern Florida Gulf Coast, in contrast, is in the early spring.

According to the funnel cloud and tornado occurrence data of Pautz (1969), tornado activity along the northern Gulf Coast is sharply diminished by summer, while funnel cloud activity in this region remains relatively high through July and August after a June peak. Gerrish (1967) noted that there were nearly six times as many funnel clouds as tornadoes in southern Florida during his 1957-66 study period. The occurrence patterns of figure 7 are thus heavily weighted toward an early spring tornado maximum along the northern Gulf Coast, and a summertime peak of funnel cloud activity in southern Florida. The Southeast Coastal region is thus unlike the other regions of the United States where the seasonal distribution of funnel clouds and tornadoes is similar.

Diurnal Distribution. Figure 8 shows the close agreement in diurnal distribution of funnel clouds and tornadoes for the entire United States. Differences are to be noted on a regional basis, however. Occurrences in the Northern

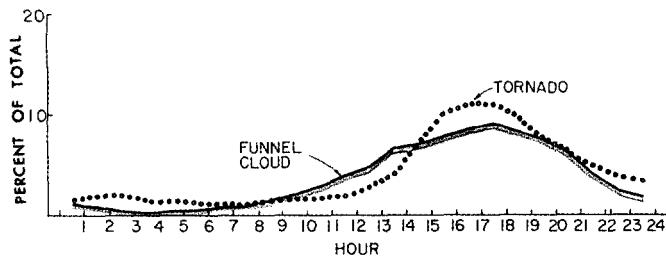


FIGURE 8.—Diurnal distribution of funnel cloud and tornado occurrences for the entire United States (based on 19 yr of funnel cloud reports, and 40 yr of tornado reports).

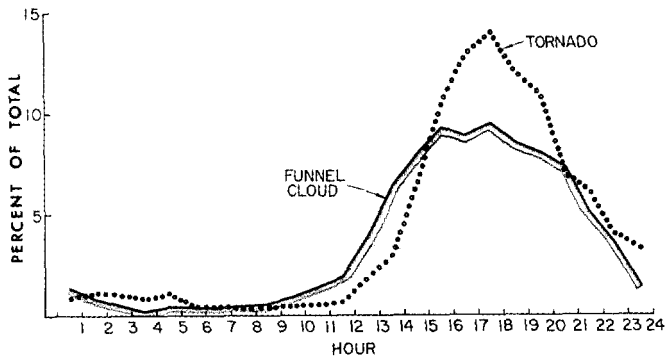


FIGURE 9.—Same as figure 8 for the Northern Great Plains.

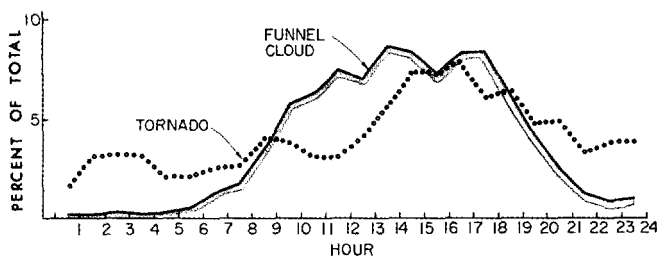


FIGURE 10.—Same as figure 8 for the Southeast Coastal region.

Great Plains (fig. 9) are much more concentrated in the late afternoon than they are in the Southeast Coastal region (fig. 10), where a more uniform daily distribution is apparent.

Figures 9 and 10 present the extremes in the diurnal distribution patterns. The other regions show occurrence patterns closer to that of the national average. Inland occurrences show a stronger dependence on time of day and season. Coastal occurrences show less daily and seasonal extremes.

Geographical Distribution. Figures 11 and 12 depict the geographical distribution of funnel clouds and tornadoes, respectively, over the United States. These distributions are based on area-normalized state-by-state comparisons that, while of relatively low resolution, provide comparable general views of the areal distribution of these events. The isoline values should not be compared, because the funnel cloud reports for the early 1950s are not representative in their totals; only the relative magnitudes are

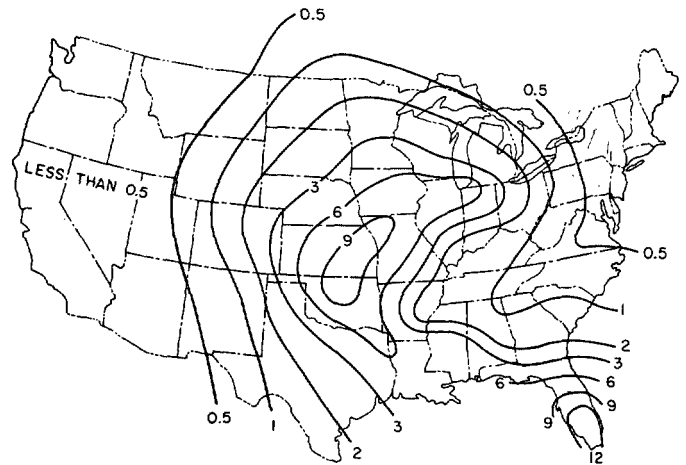


FIGURE 11.—Geographical distribution of funnel cloud occurrences. Isolines show funnel cloud occurrences per 1,000 mi² during the period 1950-69. (7,388 events)

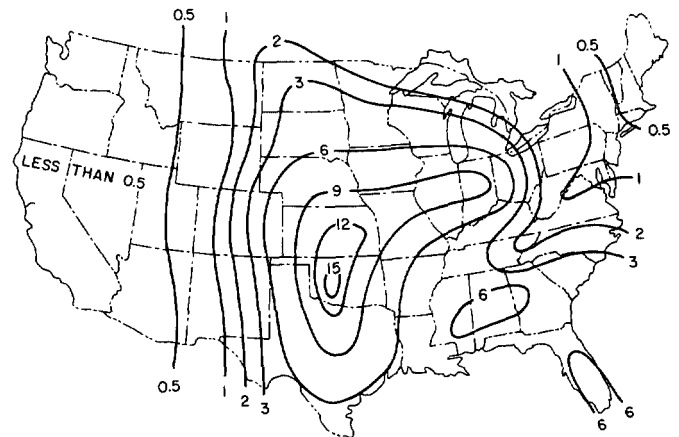


FIGURE 12.—Geographical distribution of tornado occurrences per 1,000 mi² during the period 1955-67. Data is derived from Pautz (1969).

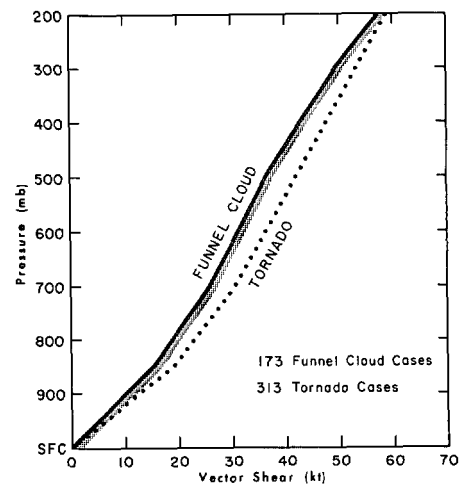


FIGURE 13.—Average magnitude of the observed vector vertical wind shear for funnel clouds and tornadoes east of the Rocky Mountains (excluding Florida and the Gulf Coast). The shear is computed at standard pressure levels with respect to the surface wind. Tornado data is from Wills (1969).

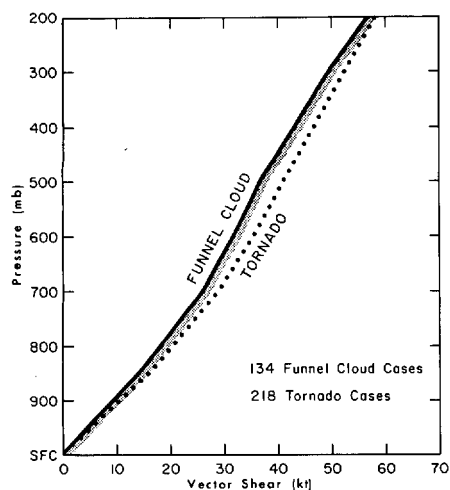


FIGURE 14.—Same as figure 13 for the Northern and Southern Great Plains.

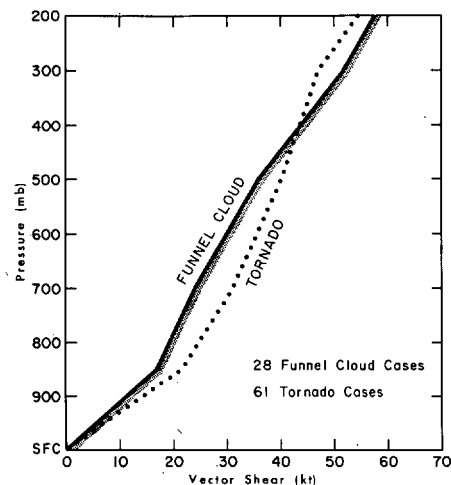


FIGURE 15.—Same as figure 13 for the East Central United States

considered representative. The figures show only the similarity of the patterns of distribution.

Figures 11 and 12 show that there is an excellent general agreement between the patterns of funnel cloud and tornado frequency considered on a per 1,000-square mile basis. On this basis, the national peak of funnel cloud occurrence is in southern Florida where tornado frequency is lower. In addition, the funnel cloud frequency over central Mississippi and Alabama is considerably less than the tornado frequency.

TROPOSPHERIC VERTICAL WIND SHEAR

This parameter has been carefully monitored and is observed to be large for most funnel cloud occurrences. Compositing of the vertical wind shears for individual occurrences was accomplished by first computing and averaging u and v wind components at standard pressure levels from the surface to 200 mb. The magnitude of the vertical wind shear vector between each standard pressure level and the surface was then determined.

Figure 13 shows the average magnitude of the observed vector vertical wind shear associated with funnel cloud

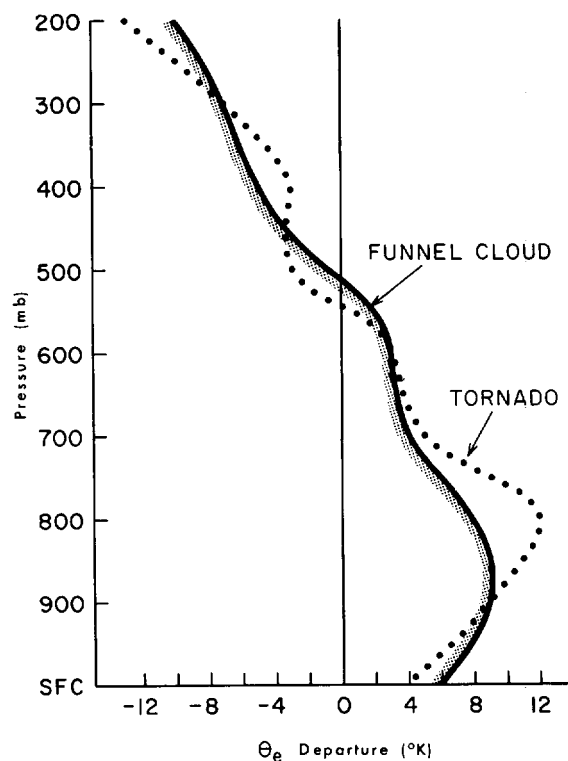


FIGURE 16.—Departure of the observed mean environmental vertical profiles of θ_e for funnel clouds and tornadoes from the mean θ_e profile for the Great Plains at 45°N in July. Tornado data is from Wills (1969).

occurrences in the United States east of the Rocky Mountains. Comparative tornado data from Wills (1969) is also shown. The Gulf Coast States of Mississippi, Alabama, and Florida have been excluded from this composite for reasons previously stated. The funnel cloud and tornado exist in very similar vertical wind shear environments. Note the large lower tropospheric vertical shear in both cases. Wills (1969) previously noted this association for tornadoes. Large vertical shear is thought to be a fundamental dynamical ingredient of funnel cloud and tornado genesis.

A similar close relationship of funnel clouds and tornadoes with an environment of large vertical wind shear is shown in figures 14 and 15 for the Great Plains and the East Central United States, respectively. Little variation in the magnitude of environmental vertical wind shear is noted.

CONVECTIVE INSTABILITY

The mean funnel cloud equivalent potential temperature (θ_e) profile for the Great Plains in the warm air masses and the corresponding mean profile of θ_e for the tornado warm air mass cases of Wills (1969) were compared with a climatological mean θ_e profile for the Great Plains at 45° N during July. The greater potential buoyancy of these profiles relative to that of the climatological mean is shown in figure 16. The destabilizing presence of potentially warmer and/or more moist air at lower levels, and potentially colder and/or dryer air above, is evident.

There is little detectable difference between the moist buoyancy potentials of the funnel cloud and the tornado soundings.

5. CONCLUSIONS

In a statistical sense, the climatological features and environmental conditions associated with the funnel cloud and the tornado appear to differ only in very minor respects. The environmental condition of *large lower tropospheric vertical wind shear* associated with funnel clouds must be noted. Cumulonimbus penetrating an environment of large lower tropospheric vertical wind shear appears to provide the dynamic setting for funnel cloud formation in a manner similar to that hypothesized by Gray (1969) for tornado genesis.

ACKNOWLEDGMENTS

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